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BECKMAN INSTRUMENTS, INC.

A SMALL ROTARY VAPOR COMPRESSION STILL FOR THE PRODUCTION OF PYROGEN-FREE WATER

CONTRACT NUMBER DA-49-193-MD-2261

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A B S T R A C T

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In April of 1962, the U.S. Army Medical Research and Development Command awarded a contract to Beckman Instruments, Inc., with Battelle Memorial Institute as a subcontractor, for the development of a rotary vapor compression distillation unit capable of producing fifty (50) gallons per day of pyrogen-free water for use in the preparation of injection water. The unit was required to be portable and capable of accepting feedwater ranging from saline to brackish and contaminated surface water. Battelle undertook the initial design study and fabricated two experimental distillation units for evaluation. These units produced distillate of a quality conforming to the criteria for Sterile Water for Injection, U. S. Pharmacopeia XVI (1960) which actually surpasses the quality demanded by the project goal. Design of two prototype units, based upon experience gained from the experimental stills, is no in progress at Beckman Instruments, Inc. It appears that these units will not only meet the water quality requirements but will produce substantially more distillate than the fifty (50) gallon per day design goal.

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PRELIMINARY DESIGN CONSIDERATIONS

At the beginning of the design study, it was recognized that the single most important requirement for the distillation system was a physical configuration that would ensure complete separation of the vapor and distillate from the feed and residue fluids. The basic configuration of the laboratory model evolved from this single consideration. Thermal and mechanical factors affecting efficiency, size, weight, corrosion resistance, and protability of the system were, of course, considered during the design study but only insofar as they did not compromise the separation of the system fluids.

To consider the fluid separation problem more specifically, three mechanisms for water droplet generation that could cause contamination were considered in the basic configuration study; they were: splashing of the feedwater stream impinging on the rotor plate, boiling of the water film, and atomization of the residue fluid upon leaving the rotating surface.

It was considered that boiling would be the least serious of these three and that it could be controlled by varying the pressure and consequently the temperature in the condensing cavity.

To qualitatively assess the two remaining mechanisms, a simple experiment was conducted. In the experiment, the minimum feed rate required to maintain a stable water film over a 12-inch diameter copper disc rotating at speeds up to 1750 rpm was examined. Since there was no evaporation of the feedwater in this experiment, the measured feed rate from each run was equated to the residue flow rate that would be required in actual still operation. Subsequent runs indicated no detectable water droplet formation from splashing of the feedwater stream but, as was expected, atomization of the residue at the edge of the rotor was significant at all rotor speeds.

From this evidence, it was decided that the exit point or points of the residue from the rotating unit was the single most important contamination source and consequently should be as completely separated from the condensing and evaporating cavities as possible. It was from this consideration that the flat plate covered on both sides by stainless steel bowls was chosen as the basic configuration.

Provision for the introduction of feedwater to the plate and withdrawal of water vapor from the top cavity was made by cutting a circular hole in the top dish and locating a stationary plate so as to form a labyrinth-like path between the space inside the cover and the evaporation cavity. Vapor generated in the evaporator cavity, after passage through a compressor, was introduced into the bottom cavity. A labyrinth-type shaft seal of Teflon was designed for this connection. The distillate and the non-condensable gases were withdrawn from the corner formed by the heat exchanger plate and the vertical sides of the bottom bowl by a stationary S-shaped tube lying in a horizontal plane just below the plate. A tee connection at the center of the "S" to a vertical stainless steel tube conducted the distillate down and out of the still to the collection container.

The residue was removed from the rotor through two small tubes piercing the sides of the top bowl just above the rotor. This placed the source of dirty water droplets, the end of the runoff tube, outside the rest of the distillation system. To contaminate the distillate, the droplets generated would have to re-enter the system through the labyrinth passage between the rotating top dish and the stationary top plate or pass back through the residue runoff tubes. Only the former seemed a practical possibility. A neoprene gasket with an inner diameter just slightly greater than the outer diameter of the top dish was placed above the residue runoff tubes to provide additional baffling and containment.

Vapor compression distillation units have, for the most part, been operated under vacuum. The operating pressures, of course, determine the temperatures at which evaporation and condensation take place. Vacuum operation with its lower operating temperatures has several advantages, namely:

(a) Smaller heat losses to the environment are encountered.

(b) Less "warm-up heat" is required.

(c) A wider selection of materials and components are available for system construction.

(d) The severity of the corrosion and scaling problem is reduced.

Operation at and above atmospheric pressure also has a number of advantages which were considered to be overriding in this application.

(a) The vacuum pump and the accompanying vapor losses may be eliminated from the system.

(b) The sealing requirement for the system container can be reduced or eliminated.

(c) The maintenance or production of an aseptic condition in the vapor and distillate lines should be more easily accomplished.

(d) The size of the vapor lines and the compressor can be reduced because of the increased vapor density at higher pressures.

(e) No special equipment or provision are required to accomplish withdrawal of the distillate and noncondensables from the condensing cavity.

The maximum operating pressure difference between the evaporating and condensing sides was set tentatively at 2 psi. The limiting factor on this upper limit is the deformation of the rotor plate. The minimum pressure difference will be regulated by the area of the heat transfer surface and that total heat transfer coefficient achieved across this surface.

A rotational speed of 1725 rpm was tentatively chosen for the laboratory model. This seemed to be a reasonable goal on the basis of the film stability experiment results. Previous experience and theoretical calculations indicated that sufficiently high total heat transfer coefficient of the order of 4000 BTU/hr-ft^2-°F could be achieved across the rotor at this speed.

COMPONENT SELECTION AND DESIGN

The separate component selection and/or design followed after the selection of a basic configuration and set of operating conditions. The specifications and considerations affecting each component are briefly discussed in the following paragraphs.

Distillate Scoop Nozzle

The distillate scoop must convert the kinetic energy of the collected distillate to static head in the withdrawal line as efficiently as possible and with a minimum of splashing. Splashing in the condensing cavity would not be a source of contamination since all of the fluids in this space are "clean". However, distillate splashed into the vapor inlet tube could not easily be removed. Two adverse effects might arise from this condition. Condenser cavity pressure might be affected during still operation by percolation of this trapped fluid. Secondly, this fluid, if allowed to remain stagnant while the still was inoperative, would provide a potential broth for bacterial growth that would be difficult to purge in subsequent runs.

An empirical approach was taken to determine what nozzle shape would perform most satisfactorily. A shallow dish machined from flat plate stock was rotated at speeds up to 1750 by a variable speed motor in this experiment. Nozzles of various shapes were formed from 1/4-inch copper tubing. The tubing was bent so the angle between the tangent to the distillate film at the point of nozzle contact and the centerline of the tubing just before the nozzle was less than 20°. The majority of the nozzles examined were formed by simply slicing the tubing vertically so the exposed face of the nozzles formed a small angle with the tangent to the distillate film at the point of contact. No detectable difference in performance of these nozzles was noted as long as the nozzle face was "opened" to the moving film and the angle between the face and film did not exceed 20°. This was the nozzle shape that was chosen for the laboratory model. Other shapes that were evaluated included a flared tube cut in a manner similar to nozzles described previously. No change in the amount of splash was accomplished by flaring except to increase splash at high residue runoff rates. Blunt entrance shapes with the contacting tube wall filed and sharpened were totally unsatisfactory confirming previous experience in this design area. One nozzle with its face opening in an essentially inverted position from that first described was tested. The fluid impact at the nozzle face caused an outward radial force resulting in excessive vibration and splashing.

In all of these tests, the withdrawal tube pointed upwards, a reversed attitude from that anticipated in the still. However, this allowed a simulation of back pressure in the withdrawal line. A static heat of 14 to 18 inches of water was generated by the best nozzle shapes at a rotor speed of 1750 rpm.

Compressor

The compressor in the system must receive the steam from the evaporating cavity as saturated vapor, compress and discharge the steam as superheated vapor. To meet the production requirement of the still, approximately two (2) gallons of distillate an hour, the compressor must have a capacity of 8 cfm at a pressure ratio of 1.2. Perhaps the most stringent requirement for the compressor was that it must introduce no contaminent into the working fluid. As with all equipment operating on steam, the materials of contruction must withstand corrosive attack. Reliability, size, and weight were secondary considerations in this initial selection phase since modification of the selected commercial unit could be effected before installation in the prototype system.

A letter containing the requirements and performance characteristics outlined above was sent to 48 compressor manufacturers. The response was entirely negative except for replies from M-D Blowers, Inc. and a late response from Leiman Brothers, Inc. As was expected, both companies suggested rotary, hinged, or sliding vane type compressors. The unit ordered from M-D Blowers, Inc. was their model SP-DA3 sliding carbon vane compressor modified by replacing those plain carbon steel parts that would be subject to corrosive attack with stainless steel or aluminum counterparts. An order was placed with Leiman Bros. Inc. for three modified hinged-carbon-vane units, 2 each of 295-2 and 1 each of 206-3. All three units were to be fabricated from stainless steel as special units. The Leiman units were promised on 10 weeks delivery. After 16 weeks had elapsed from the order date, the manufacturer indicated that several more weeks would be required before completion of the compressors. Acquired experience with carbon vaned compressors and the excessive delay prompted cancellation of the order at that time.

The M. D. Blower compressor was delivered in August before fabrication of the still was complete. Initial testing of this compressor to determine its performance characteristics utilized laboratory line steam as the working fluid and a water cooled glass condenser to allow collection and visual examination of the exhaust product. The first run resulted in a failure of the carbon vanes, causing damage to the housing and rotor. It is perhaps also appropriate to note here that disassembly of the unit at this time revealed that the rotor shaft and shaft seal housings furnished were plain carbon steel, and consequently, some corrosion had taken place. Replacement of these parts was deferred until final evaluation of the unit was completed. Testing was resumed in August after the unit was repaired. Examination of the discharge fluid from this compressor revealed gross and excessive contamination from carbon wear particles. Since the compressor appeared to be performing adequately as to pumping capacity, Teflon vanes were fabricated as replacements for the carbon vanes. The Teflon blades decreased the degree of contamination from wear particles. However, flexing of these blades also reduced the pumping capacity of the unit.

Disassembly and inspection of the compressor after 2 hours of operation showed aluminum wear particles imbedded in the Teflon vanes and severe scoring of the contact surface of the aluminum housing. The housing was rebored and inspected. The aluminum from which this housing had been machined appeared to be rather pourous. For that reason, a polished aluminum sleeve was press fitted in place to renew and replace the housing contact surface. Subsequent testing revealed some improvement in compressor performance. However, the contamination from Teflon particles persisted.

During this period, the compressor division of Conde Milking Machine Company was contacted. They felt that their Model Number 3SW-CCW rotary sliding-carbon-vane compressor could successfully meet the requirements of the systems. All internal parts and surfaces in this unit were spray coated with Teflon. One such unit was ordered and tested. Its performance was not significantly better than the M. D. Blower compressor. The Teflon coating on the rubbing surfaces was quickly worn away. The cast iron cylinder did appear to cause a little less wear of both carbon and Teflon vanes. However, corrosion commenced as soon as the Teflon coating on the cylinder was dissipated.

Initial System Evaluation

Despite the shortcoming of these compressors, they were used for the initial system check out. A 500-watt feedwater heater was installed in the system.

The still was not capable of self sustained operation during the first series of tests even after being brought up to operating temperature by line steam injected into the rotor housing. In addition, leakage at the Teflon shaft seal during the initial runs appeared to be above a tolerable level and continued running to wear the joint in did not seem to improve its performance. The rotor shaft was modified and a Deublin Rotating Duoflow Steam Union Model 255 was installed to replace the originally designed seal. The union operated in a very satisfactory manner to decrease steam leakage; however, it also increased the friction load on the drive motor. It was noted in the attempts to achieve self-sustained operation that the still operated normally until the line steam was shut off, at which time, the evaporating pressure dropped below atmospheric while the condensing pressure increased or remained constant. At the same time, the temperatures of both sides decreased rapidly as did the temperature difference between the evaporating and condensing cavities. Indications were that air was leaking into the system in large enough quantities to block condensation. This was verified by submerging the end of the distillate withdrawal line in a water-filled glass container and observing the increase in the amount of noncondensable gases in the exhaust when the line steam was cut off.

Modified System Testing

It was also obvious from the temperature record of this test that heat was being lost as specific heat in the residue and distillate. For that reason, a three-fluid-counterflow heat exchanger was installed to improve the thermal performance of the system.

Two new compressors were obtained and modified for use in the system. The first was a small diaphragm compressor whose pumping capacity was known to be below that required for the system. The second was a vacuum sweeper blower fabricated from aluminum and plain carbon steel. Neither of these compressors was throught to be completely appropriate for the system in the form in which they were tested; however, the tests allowed us to evaluate the potential of each type before further modification. Use of the diaphragm unit also allowed us to eliminate the compressor as a potential source of air leakage and thus assess leakage into the rotor housing.

The centrifugal compressor leaked an excessive amount of steam and condensate along the motor shaft to the motor housing during the first test. Results were otherwise encouraging enough to justify a rather extensive modification of the unit to provide adequate sealing.

Tests conducted with the diaphragm compressor installed in the system determined that air leakage through the rotor housing and into the evaporating cavity was itself sufficient to preclude self-sustained operation of the still. It was decided that a redesign of the system to provide adequate sealing would be required. Sealing the top rotor dish rather than the housing seemed the best solution to the leakage problem. This approach had two advantages. It allowed removal of the residue fluid from the rotor housing without resorting to a special pump and eliminated the necessity of providing an air tight seal at every point where piping pierced the rotor housing.

Because of the time required to design and fabricate the new top rotor, testing was continued on the old configuration. A simple temporary modification was made to seal the rotor housing. After this change, the old system proved to be capable of self-sustained operation when warmed to operating temperature by the injection of line steam. The production capacity of the system with the sliding-vane compressor was slightly below two gallons an hour; however, this was attributed to the decreased mechanical performance of the compressor after the substitution of Teflon vanes (P = 1.0" Hg). The measured heat transfer coefficient across the rotor was approximately 5000 BTU/hr ft^2-F.

Redesigned Top Rotor Testing

The fabrication of the new rotor assembly was completed in early November 1962. The new top rotor dish was closed at the top to a threaded fitting welded in place. A Deublin rotating union installed in this fitting allowed the withdrawal of vapor and injection of feedwater. For initial testing of the thermal performance and contamination characterisitcs of the new configuration, the small diaphragm compressor was connected to the still. The new system proved to be capable of self-sustained operation, but again pre heating with auxiliary steam had been employed.

A test was then conducted to determine how much extra heater capacity would be required to allow startup without the use of auxiliary steam. The feedwater rate was adjusted to approximately 60 cc/minute with the 500-watt heater switched on. No other heat source was utilized. The temperatures of the various parts of the system were monitored. After approximately one hour, the evaporator and condensing cavities were near 212°F, at which time, the compressor was started. The condensing-side temperatures decreased temporarily while the compressor was warming up. The system gradually recovered until self-sustained operation was achieved. While the time required for this startup was rather long, the fact that enough heat was available from this small heater to achieve startup was encouraging.

Water Quality Tests Conducted at Beckman Instruments

Although additional work remained to be done, one of the experimental stills was shipped to Beckman Instruments on October 19, 1962, in order to demonstrate its operation and to acquaint Beckman personnel with the existing problems. Meetings between Messrs. Donner, Hartman, Charlton, Van Arnam, and Lucero of Beckman and J. R. Irwin and J. R. Pingry of Battelle were held in Fullerton, California during the period from October 30 to November 1, 1962.

While Battelle was primarily concerned with solving immediate mechanical design problems, Beckman was interested in using the experimental still to conduct experiments on the quality of distillate that could be produced by rotary vapor compression distillation.

It was important to verify that the evaporation section of the still could produce vapor with little or no liquid carryover. Because of Teflon leakage from the compressor vanes it was felt that a pyrogen test on the distillate would be meaningless. For this reason a chloride ion determination was utilized. Tap water, containing 122 ppm of chloride ion was used as feedwater to the still. Distillate samples averaged only 0.8 ppm of chloride ion as compared with 2.4 ppm for water samples from a conventional Barnstead laboratory still. This indicated that the efficiency of removal of the chloride ion was on the order of 99.3%. Although this test was preliminary it did indicate that the design of the evaporating section showed promise of producing pyrogen-free water.

Water Quality Tests Conducted at Battelle

Battelle also conducted tests intended to show the extent of liquid carryover. Initial tests were made using a fluorescent tracer method. Tap water was used as feed and was treated with a fluorescent dye. Distillate was compared with the tap water and with a commercially distilled water. A fluorophotometer comparison indicated a high degree of flourescent contamination in the distillate sample. Investigation revealed that the total steam system had become contaminated with grease, apparently from the top rotating union bearings. After the system was cleaned and reassembled, another run was started. Distillate from this system indicated a contamination level roughly equal to that measured in plain tap water. In an attempt to determine the source or sources of this contamination, a subsequent run was made wherein the water vapor was withdrawn to a glass condenser immediately after passing through the top rotating union. This eliminated the compressor, bottom union, condensing surface and distillate withdrawal tube as potential sources of contamination. The fluorophotometer reading on this distillate was unchanged from the previous runs, indicating possible contamination from the evaporation cavity. It was felt that more conclusive tests should be conducted in order to determine the exact source of the contamination. On this basis, a test was conducted using a feedwater contaminated with cobalt nitrate. The water vapor leaving the evaporating cavity was again withdrawn directly to a glass condenser. Any cobalt detected in the distillate from this run could be attributed to carry-over in the still and thus allow a quantitative evaluation of this contamination mechanism. Runs were also made using plain tap water and commercially distilled water as feed waters. A distillate sample was collected during each of these runs after the still had been in operation for 45 minutes and again after 105 minutes. Samples of the distillates and feedwaters were analyzed by the Institute's emission-spectroscopy group. The encouraging results of their initial analysis are shown in Table 1.

TABLE 1. WATER ANALYSIS USING EMISSION SPECTROMETER

	Parts Per Million (Approx)				
	Mg	Cu	Ag	Co	Ca
Distillate 1	0.1	1-10	1-10	--	.3
Distillate 2	0.3	1-10	1-10	--	.3
Distillate 3	0.3	1-10	1-10	--	.3
Distillate 4	0.3	1-10	1-10	--	.3
Distillate 5	0.01	0.1-1.0	0.1-1.0	1.0	0.5
Distillate 6	0.05	0.1-1.0	0.1-1.0	1.0	0.5
Distilled Feed Water	0.3	1.0-10	1.0-10	--	0.3
Plain Tap Feed Water	10	0.1-1.0	0.1-1.0	--	50
Cobalt Tap Feed Water	10	0.1-1.0	0.1-1.0	200	50

-- Indicates no detectable trace.

Distillates 1 and 2 are samples from the run using distilled-water feed; Distillates 3 and 4 from the plain tap water feed run, and Distillates 5 and 6 from the cobalt nitrate contaminated tap water feed run.

Since the total contamination level appeared to be of the order of 20 ppm, the maximum allowable for USP injection water standards, a distillate sample was taken from the same mechanical system using tap feedwater and tested for pyrogen content by the standard pyrogen assay using test rabbits.

The total system including the condenser was washed with steam from the evaporator side of the still for 30 minutes before the cooling water to the condenser was turned on. The system was then allowed to operate for another 30 minutes before any distillate was collected. Collection was made in an aseptic, rubber-capped bottle fitted with collection and vent tubes to No. 8 hypodermic needles piercing the cap. The bottle was prepared by adding the required amount of pyrogenfree NaCl for 500 cc of isotonic saline solution. After collection, the hypodermic needles were removed and the sample stored under refrigeration for approximately 48 hours before use. Five rabbits were used in the pyrogen test. Numbers 1, 2, and 3 were injected with solution collected from the still. Number 4 was injected with commercially prepared pyrogen-free solution. Number 5 was injected with an isotonic saline solution prepared from plain tap water. The rabbits were weighed and 10 cc of solution per Kilogram of rabbit body weight was injected in each case. The temperatures of the rabbits were measured and recorded at 1 hour intervals after injection. The test results are shown in Table 2.

TABLE 2. TAP-WATER PYROGEN ASSAY

Rabbit	Preinjection Temperature in °C	Temperature Deviation From Standardized Control Temperature			
		1 hr.	2 hr.	3 hr.	4 hr.
No. 1	39.2	-0.1	-0.9	-0.7	-0.5
No. 2	39.5	+0.1	-0.3	-0.1	+0.2
No. 3	38.9	+0.4	+0.2	+0.3	+0.3
No. 4	39.6	+0.1	-0.2	-0.2	+0.3
No. 5	39.4	+0.1	+0.0	+0.7	+0.7

The test indicates that the tap water pyrogen content, while not excessive, was high enough to cause the control test rabbit (No. 5) to fail the U. S. P. pyrogen test since a temperature rise of 0.7 degree C was recorded 3 hours after injection. However, because of the moderate febrile response in the control rabbit, it seemed advisable to repeat this test using a feedwater with a higher pyrogen content. On this basis, two rabbits were injected with filtered water from the Olentangy River to determine its suitability as a feedwater. Both rabbits showed a temperature increase of 1.3 degrees centigrade one hour after injection. Three hours after injection their temperatures were 1.5 and 2.3 degrees centigrade above their respective standardized temperatures.

The run previously described was repeated on January 9, 1963, using Olentangy River water as feed. Eight (8) rabbits were weighed and placed in restraint. Three of these were rejected after their pre-injection temperatures indicated a lack of conditioning to the restraint. Four (4) of the remaining rabbits were injected with 10 cc of the collected isotonic saline solution per kilogram of body weight. Rabbit Number 5 was similarly injected with a solution prepared from the undistilled river water. The results of the test are shown in Table 3.

TABLE 3. RIVER WATER PYROGEN ASSAY

Rabbit Number	Pre-injection Temp. (C)	Temperature Deviation From Standardized Control Temp. (C)		
		1 hr	2 hr	3 hr
1	39.0	+0.3	+0.4	+0.5
2	39.0	+0.2	+0.0	+0.1
3	39.6	+0.0	+0.0	+0.0
4	39.0	-0.1	-0.1	+0.0
5	39.6	+1.6	+2.0	+2.5

The temperature deviation of rabbit number 5 was 2.3 and +1.6 C after four and five hours respectively. The temperature of this rabbit had returned to 39.5 C when measured the following morning, twenty hours after injection.

A sample of the same solution was submitted to the Pathogenic Microbiology Section of the Biosciences Division for sterility tests as outlined in the U. S. Pharmacopoeia. Six broth tubes were prepared, three of Sabouraud liquid medium and three of thiogylcollate. In addition, four aliquots of the solution were pour plated directly in blood agar base agar (Difco) fortified with a 0.2 per cent yeast extract. All agar plates and broth tubes were incubated at 37 C and examined at the end of 24, 48, 72, and 120 hours.

All of the cultures were negative except one agar plate which developed three surface colonies after 24 hours which were evaluated to be fungi from laboratory contamination.

A sample of the distillate was collected immediately following the preparation of the saline solution and analyzed by Battelle's emission spectroscopy group. The results showed the following constituents, in parts per million: Copper, less than 0.1; Silver, less than 0.1; Magnesium, 0.2; and Calcium, 0.4.

In summary, the sample of distilled river water conformed to the criteria for Sterile Water for Injection, U. S. Pharmacopeia XVI (1960). Since the present design configuration appears to be capable of producing such a product all additional tests made on the final design configuration will include these detailed bacteriological and analytical assays. While these criteria far surpass the basic project goal of producing pyrogen-free water the production of such a high quality product should greatly enhance the potential of the still.

<u>Choice of Compressor</u>

It was agreed that in the interests of rapidly solving the development problems remaining on the still, Beckman would assist in the search for a suitable compressor. Upon first inspection it would appear that the problem of vane erosion and contamination could be solved by substitution of a multi-stage centrifugal blower. However, no such blower with the specific output requirements exists commercially. The nominal requirement for 10 CFM of steam at 2 psig indicates a four or five stage centrifugal blower operating at about 14,600 RPM.

Most reputable blower manufacturers contacted were reluctant to quote on the development of such a blower. Torrington Manufacturing Company, however, agreed to undertake the development of a blower with a guarantee on performance. They proposed that due to the nature of the material (stainless steel) and because of the critical tolerance buildup in the connecting ducts of the several stages, it would be necessary that the blower housing be made by an investment casting process. Development costs for the production of two units would be on the order of $14,000.

Battelle, in an earlier communication with Beckman, had suggested the investigation of the M-D Blower for application to this problem. Beckman was able to obtain a standard M-D Blower in Los Angeles for evaluation. Subsequent tests have indicated that this blower will meet the requirements for the rotary vapor compression still. The M-D Blower is a three-lobed positive displacement unit. As far as is known this is the smallest lobed type blower commercially available today.

Prototype Design Status

The final design of the prototype unit is now in progress at Beckman Instruments, Inc. Approximately 60% of the detail design drawings have been completed and shop fabrication is underway. The still is housed in a framework 16" wide by 19" long by 18" high. Estimated weight of the completed unit is 85 pounds. Removable sheet metal sides will permit access for maintenance while a hinged cover will expose the rotor assembly for cleaning or maintenance. Handles are provided for portability.

The entire unit is insulated to aid in recovery of waste heat. Special high temperature aircraft motors are employed to drive the compressor and rotor in this environment. The inside of the housing will be in excess of 200° F. At an ambient temperature of 100° F., the external skin temperature of the housing will be 130° F.

Additional thermal studies are being conducted concurrently with the final design phase in order to properly size heat exhangers and select components. A computer study of the overall heat balance of the system is underway. Results will aid in determining the insulation requirements and operating parameters. Current work indicates that the unit will produce substantially more distillate than the 50 gallon per day design goal.

The M-D Blower is being incorporated into the still design. Bench tests have shown this compressor capable of providing the necessary output but additional tests are being conducted concurrent with the design phase. This compressor is designed for steam service and has successfully handled steam both at Beckman and Battelle. In future designs it is felt that considerable savings in weight could be achieved by a redesign of the compressor housing.

The vaporizing and condensing sections of the still make use of the Battelle design, which has produced high quality distillate. Beckman's design effort has been directed toward improvement of mechanical design features. For example, the rotating unions have been replaced by rotating hard carbon face seals to prevent inleakage of lubricant.

In addition, special attention has been given to location and orientation of components to achieve a minimum size with adequate provisions for access.

Two prototype stills are being fabricated. Upon completion they will be evaluated both by Beckman and Battelle. Beckman will emphasize performance tests while Battelle will conduct an extensive test program on the quality of the distillate. Upon satisfactory completion of tests, both units will be delivered to the U. S. Army Medical Research and Development Command.